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THE ENDOGENEITY OF MONETARY POLICY IN THE NETHERLANDS: Two reaction functions of the central bank

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1. Introduction

Empirical analysis of decision behaviour is quite common in micro-economics but less familiar in macro-economics. This paper estimates two macro-economic reaction functions of the Dutch central bank for two policy instruments, viz. the discount rate and credit control. The issue of the endogeneity of policy instruments is crucial for our understanding of policy behaviour. The importance of this question is illustrated by the fact that the usual macro-economic policy models are based on the implicit assumption that the policy instruments are exogenous. Evidence about the responsiveness of the policy variables to the targets of economic policy may question this assumption. To look at this and carry the implications further by considering an analytical solution is another purpose of this paper.

The plan of the paper is as follows. Section 2 gives a short description of the most important instruments of monetary policy in the Netherlands. Section 3 presents the theoretical framework of our analysis and derives the reaction function as the result of optimizing behaviour of the policy maker. In section 4 two reaction functions are postulated and estimated for the sample period 1958:I - 1975:IV. The reaction function of discount rate policy is a standard regression equation relating the official interest rate on advances to the main targets of stabilization policy. This approach seems less suitable to estimate the credit restriction reaction function in view of the discrete nature of credit control policy. Therefore, a qualitative regression model is employed to estimate an appropriate reaction function. In order to compare our results with the main findings of others, section 5 presents a survey of previous investigations of reaction functions. The final section summarizes the main conclusions and raises a few methodological issues related to the existence of reaction functions and indicates how to deal with some of those difficulties.

2. Instruments of monetary policy in the Netherlands

The central bank in the Netherlands is responsible for monetary policy, but, as monetary policy is closely associated with the Government's fiscal policy, the Bank Act of 1948 enables the Minister of Finance to give directives to the Bank for coordinating its monetary and financial policies with those of the Government. Until now, this authority, which is a remedy of last resort and a constituent part of parlementary democracy, has never been used. Within this rule the Bank has a great deal of independency to achieve the objectives, outlined in Section 9, Subsection 1, of the Bank Act of 1948 stating that:

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«It shall be the duty of the Bank to regulate the value of the Netherlands monetary unit in such a manner as will be most conductive to the nation's prosperity and welfare, and in so doing seek to keep the value as stable as possible.»

The Bank has at its disposal a number of instruments to carry out its policies. The discount rate is a monetary instrument of long standing. During the nineteen-fifties this policy was supported by open market policies and cash reserve requirements, which in those days aimed at restricting the commercial banks' excessive liquidity. After 1958, when the external convertibility of the guilder was restored and the commercial banks started to build up a substantial volume of net foreign assets, the Bank conducted a policy of direct credit control from time to time. As a result, liquidity control lost its meaning for controlling money supply. However, in 1973 this policy was abandoned and replaced by a new system of indirect credit control. Meanwhile the money market instruments of cash requirements and open market policy, often conducted in the form of interventions in the foreign exchange market, remained useful. However, after 1958 the main monetary instruments were discount rate policy and credit control. Therefore, we shall focus our analysis on these two instruments exclusively, neglecting the other means only for the sake of simplicity.

2.1. Discount rate policy

In order to augment their liquidity position the banking system has recourse to the Netherlands Bank by discounting approved short-term money market paper and borrowing against securities. The discount rate on bills of exchange applies to the discounting of Treasury paper. The discount rate on promissory notes is important only because the banking system traditionally uses it as a basis for its lending rates. The interest rate on advances is the rate of interest at which advances can be obtained; it is usually 1/2% point higher than the discount rate on bills of exchange (1) and is always equal to the discount rate on promissory notes. In practice advances play a more important role than re-discounts, as is illustrated by e.g. the figures for 1975. In 1975, the average outstanding amount of domestic lending by the Bank was Fl. 369.5 million, of which the advances on current account amounted to Fl. 342.9 million i.e. almost 93 % of total lending.

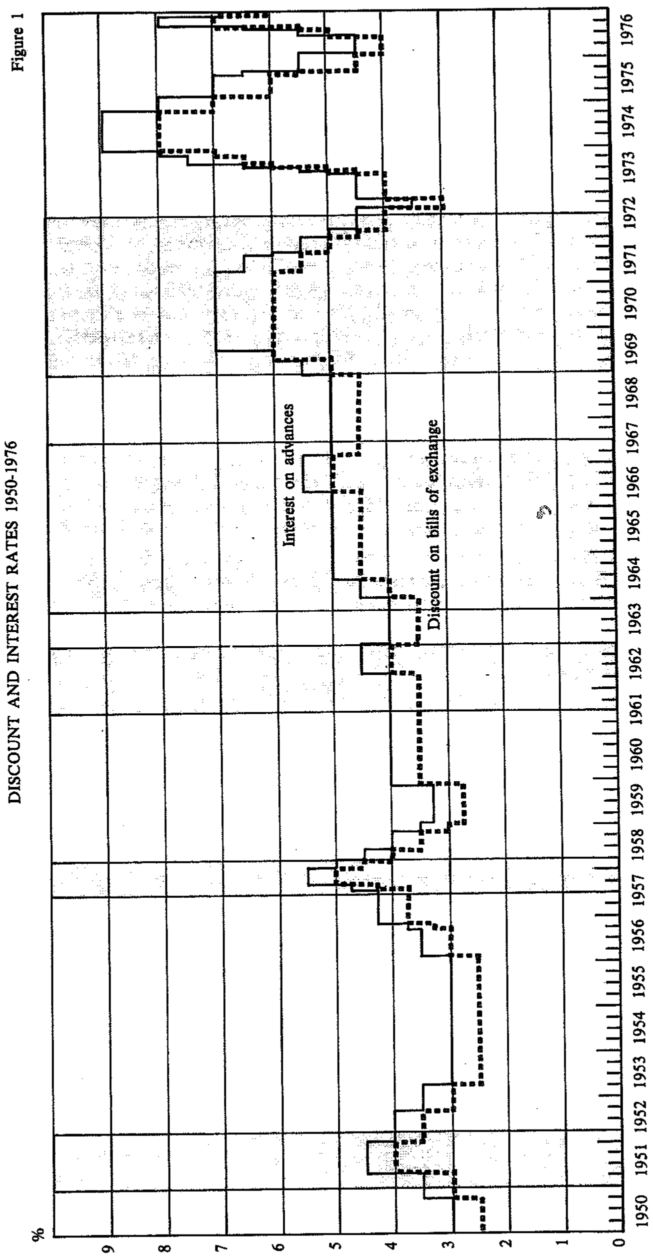
Since 1950 the discount rate on bills of exchange and on promissory notes has been adjusted 49 times; the interest rate on advances 48 times. Over the period 1958-1976, which is more important to the present analysis, the number of changes for all rates was 39, averaging 1 per 2 quarters. In the postwar period the lowest rates have been 2 1/2 % and 3 % (1953-55) and the highest 8% and 9% (1973-74). Over the years 1958-1976 the lowest rates were 2 3/4% and 3 1/4% (1959) respectively. Figure 1 shows the fluctuations of the interest rate on advances and the discount rate on bills of exchange since 1950 with shaded areas indicating periods of credit restriction. We note that particularly before 1958 credit restriction and high discount rates always coincided.

It should be emphasized that, in the official statements, the reasoning behind discount rate policy has gradually changed over the years. During the first two decades after the war prime consideration was given to the balance of payments, fluctuations in the volume of lending and the money market situation. In the second half of the sixties discount rate policy has been increasingly dictated by movements in the money market rates, both domestic and foreign. Occasionally it was also applied to support the policy of direct credit restriction that has been in force since 1961. Thus, discount rate policy was primarily meant to affect the structure of interest rates and the availability of bank credit rather than the demand for bank credit.

(1) Between August 1969 and August 1971, October 1973 and February 1976, and since August 1976 1% point higher.

Figure 1

DISCOUNT AND INTEREST RATES 1950-1976



Explanatory note: The shaded areas indicate periods of credit restriction

2.2. Credit control policy

Credit control serves to mitigate the growth rate of domestic liquidity as far as it results from lending by money-creating institutions.

In the early postwar years the Bank applied a system of qualitative credit control, whereby permission was required for credit in excess of Fl. 50,000. This system was abandonned in 1950 and replaced by a general system of quantitative credit control, compelling banks with an excessive expansion of lending to borrow from the Netherlands Bank irrespective of the fact that they had ample liquidity. One of the objectives of this new system was to support the first postwar discount rate change of September 26, 1950, raising the discount rate on bills of exchange and on promissory notes by 1/2 percentage point. In 1952 the restrictions were suspended. In September 1957 the banking system was asked to moderate its domestic lending to the private sector. Individual banks that did not restrict themselves sufficiently were only allowed to the discount window at a rate that was at least 1 percentage point higher than the official rate. In April 1958 these restrictive measures were recalled and the discount rate was lowered four times in that year. It was only in 1961 that credit restrictions were again applied.

In May 1960 the Netherlands Bank reached agreement with the commercial banks on the basis of the Act on the Supervision of the Credit System (Section 10), on a new system of quantitative restrictions on short-term lending to the private sector. According to this agreement the Netherlands Bank could prescribe a maximum growth rate of short-term lending to the private sector over a certain period of time. Banks that overstepped this limit were compelled to hold a certain interest-free deposit with the Netherlands Bank.

In 1965 this requirement was extended to the commercial banks' long-term domestic lending and in 1969 and 1970 the restrictions were also introduced for the general savings banks and the Postal Cheque and Giro Services respectively. An important consideration in introducing this system of direct credit control in 1960 was that the very ample liquidity position of the banking system at that time did not give much scope for curbing lending by tightening liquidity.

In 1973 the method of direct credit control was replaced by a system of indirect credit control. Agreement was reached with the commercial banks, the agricultural credit banks and the Postal Cheque and Giro Services that they would hold a certain amount of liquid assets with the Netherlands Bank depending on the size of their short- and long-term liabilities. In view of the economic situation in recent years and the need to counteract capital movements ensuing from credit controls, the indirect system has sofar not been applied very severely.

During the years 1958-1976 the Netherlands Bank conducted a restrictive policy in 36 out of 76 quarters; this policy almost exclusively took the form of direct control. Direct control was in force from 1961:III – 1962:IV, from 1963:IV – 1967:II and from 1969:I – 1972:II. In the present analysis we also count 1958:I as restrictive, because the restrictions introduced in September 1957 were at that time still in force. In 21 out of the 35 quarters the direct credit restrictions were effective in so far as the banks held a compulsory deposit with the Netherlands Bank.

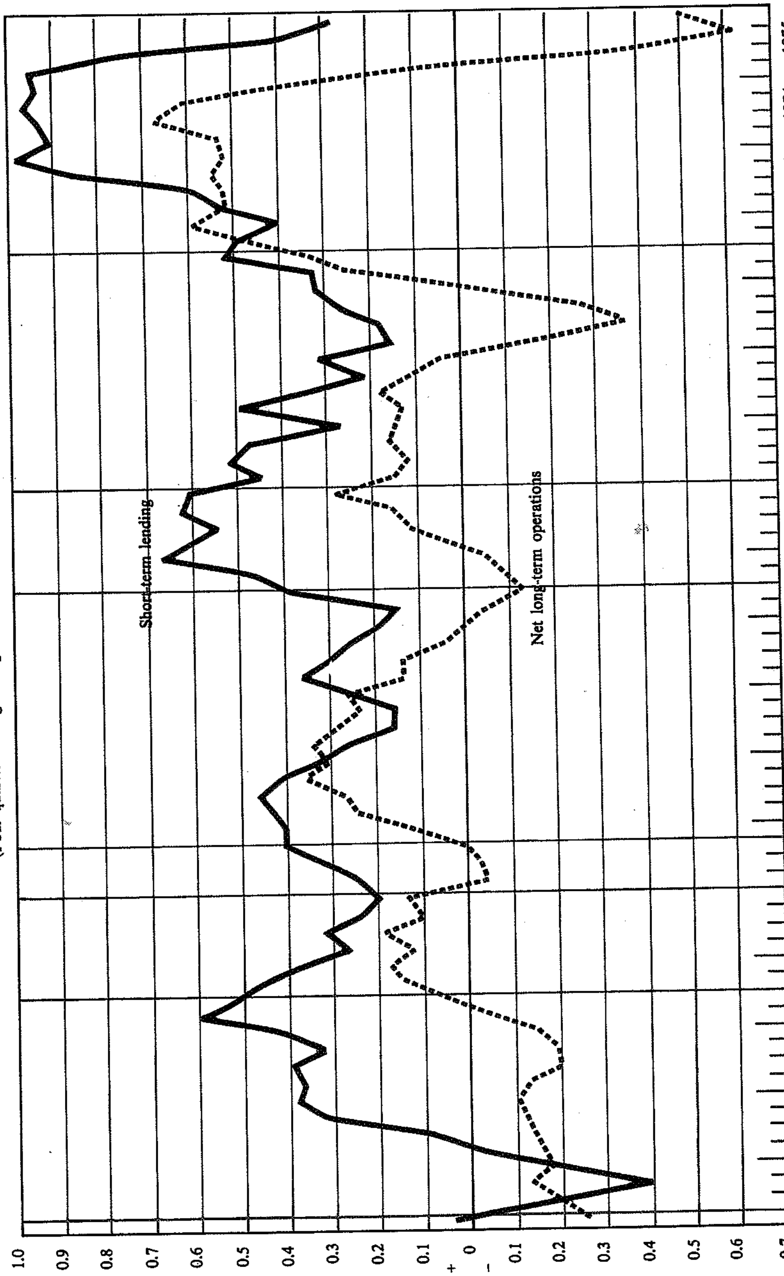
Figure 2 illustrates the credit control policy over the period 1958-1975, with shaded areas indicating periods of credit restriction. A four quarter moving average of the short-term lending to the private sector and the net long-term operations of money-creating institutions, scaled to the nominal net national income, are also depicted to illustrate the monetary background of the period.

3. Framework of analysis

In this paper we follow Theil (1964) and Friedlaender (1973) and consider a reaction function to be the outcome of an optimization process. In this framework the policy maker

Figure 2

SHORT-TERM LENDING TO PRIVATE SECTOR AND NET LONG-TERM OPERATIONS OF MONEY CREATING INSTITUTIONS 1958-1975
(Four quarter moving averages as a % of net national income)



Explanatory note: The shaded areas indicate periods of credit restriction attempts to maximize over a single period his welfare function, which is constrained by a structural model of the economy, representing the policy maker's view of the working of the economic process. We assume that the policy maker wants to achieve certain desired values both for the targets y and the instruments x. The number of instruments (q) is assumed to be smaller than the number of target variables (r). The preferences of the policy maker are summarized in his welfare function. We assume that this welfare function U (x, y) can be approximated around the desired values x^* and y^* by the quadratic loss function

$$U(x,y) = \alpha'(x-x^*) + \beta'(y-y^*) - \tfrac{1}{2}(x-x^*)'A(x-x^*) - \tfrac{1}{2}(y-y^*)'B(y-y^*) \tag{1}$$

with

- α: q × 1 vector of weights attached to deviations of actual from desired values of the instruments
- β: r × 1 vector of weights attached to deviations of actual from desired values of the target variables
- A: q × q symmetrical matrix of weights attached to the squared deviations of the actual from desired values of the instruments
- B: r × r symmetrical matrix of weights attached to the squared deviations of the actual from desired values of the target variables.

The functional form (1) assumes that no interaction exists between instruments and target variables, and therefore that the policy maker is indifferent as to the question which combination of target variables and instruments achieves the objectives. Mathematically this means that the term with cross products from the Taylor series has been neglected. A second assumption is that the structural model describing the policy maker's view on the economy is linear. From this follows that the relationship between target variables and instruments is

$$y = Rx + Sz \tag{2}$$

with

z: s × 1 vector with other exogenous variables;

R and S: r × q and r × s matrices resp. with reduced form coefficients.

In this context the optimal economic policy is determined by maximizing the welfare function U by means of the instruments, with (2) as a constraint. Substitution of (2) into (1) and equating the first derivatives of U with respect to x to zero, gives

$$\alpha + R'\beta - Ax - Ax^* - R'BRx - R'BSz + R'By^* = 0 \tag{3}$$

so that

$$x = (A + R'BR)^{-1}(\alpha + R'\beta) - (A + R'BR)^{-1}(Ax^* - R'By^*) + \\ - (A + R'BR)^{-1}R'BSz \tag{4}$$

This solution is not suitable for a reaction function, because it does not relate the instruments with the targets, which have disappeared from (4). Using (2), however, we can rewrite (3) as

$$\alpha + R'\beta - A(x-x^*) - R'B(y-y^*) = 0$$

so that

$$(x-x^*) = A^{-1}(\alpha + R'\beta) - A^{-1}R'B(y-y^*) \tag{5}$$

In this formula the instruments, deviating from their desired values, are **exclusively** determined by the target variables, deviating from their desired values. Formula (5) may be regarded as the theoretical basis for the specification of reaction functions.

From the viewpoint of economic policy it is important to know the weights α, β, A and B in the welfare function. One way to determine these weights is by interviewing policy makers, as was done in the Netherlands by Van Eijk & Sandee (1959) and Merkies (1973).

They asked the politicians about their (subjective) trade-offs between target variables. Another way, applied by Friedlaender (1973), is to calculate the revealed preferences. In the latter case it is implicity assumed that the policy maker maximizes his welfare function and that he knows the structural model of the economy. The weights are derived from the estimated coefficients of the reaction functions. However, in doing so, serious identification problems arise, particularly when the question is asked whether the policy maker bases his decisions on the reduced form of the structural model and whether he knows the coefficients R and S [see Woods (1967), Dean (1974), Nijkamp and Somermeyer (1971), Havrilesky (1977)].

As the weights of the welfare function are identifiable in particular cases only, we have not attempted to calculate them in the present study. We confine ourselves to the trade-offs, implied by the reaction function itself. These trade-offs indicate which changes in the target variables compensate for each other to such a degree that the policy maker does not alter his instrument value. We shall return to this issue in discussing our estimation results.

4. Estimation of central bank behaviour 1958:I – 1975:IV

Although the previous analysis provides a theoretical framework of our study, equation (5) is not specific enough to serve as a statistical model. Firstly, it is necessary to choose the relevant target variables. Monetary policy is primarily stabilization policy. Therefore we assume that in particular the balance on current account, full employment and price stability are relevant overall target variables. As monetary policy is not directed at growth and a reasonable income distribution, these targets are ignored in the present analysis. This is customary in case of the income distribution as a policy target, but growth plays an important role in a number of other reaction function studies. However, preliminary empirical results of ours, not reported here, support the view that growth did not affect Dutch monetary policy during the reference period. Apart from these broad goals of overall stabilization policy, more specific goals as orderly conditions on the money market and stabilization of the foreign exchange market also play a role in explaining the central bank behaviour.

As regards the instruments, our analysis is focused on discount rate policy and credit control. Unlike discount rate policy the credit restriction policy is dichotomous: a credit restriction either occurs or it does not. This means that the specification of the relevant reaction function has to meet special requirements and that in contrast to discount rate policy, an ordinary regression equation is not likely to fit this particular characteristic.

Is this section the estimation results for the Netherlands Bank' discount rate policy and credit control behaviour over the period 1958:I-1975:IV are presented. This period covers 72 quarters. The variables which the two equations have in common, have been measured in the same way throughout and are, where necessary, seasonally adjusted because the seasonal variation is deliberately ignored in preparing stabilization policy. The data used in the analysis are given in appendix A.

4.1 Discount rate policy

Discount rate policy is assumed to depend on deviations of the target variables from their desired values. We postulate the following linear specification of the discount rate reaction function

$$r_t = \alpha_1 + \alpha_2 r_t^d + \alpha_3 r_t^F + \alpha_4 B_t + \alpha_5 \dot{p}_t + \alpha_6 u_t + \alpha_7 r_{t-1} \tag{6}$$

with B the balance of payments on current account minus 1% of the net national income, which approximates the desired surplus, $\dot{p}$ the relative change in the consumer price level and u the rate of unemployment. In contrast to B the desired values of $\dot{p}$ and u are unknown and presumably constant over time. Therefore they may be included in the constant term α_1 of the regression equation. As we have remarked before, discount rate policy in the Netherlands also has more narrow monetary aims: maintaining reasonable domestic interest rate structure and the position of the guilder in the foreign exchange market. Therefore indicators for domestic and foreign short-term interest rates, r^d and r^F respectively, are included. In order to be in line with the theoretical framework they should be defined as final targets of economic policy, but we may also regard them as indicating the range in which discount rate policy has to be pursued.

As the discount rate should follow the domestic and foreign interest rates, we assume that $\alpha_2, \alpha_3 > 0$. With regard to the balance of payments it is plausible to assume that $\alpha_4 < 0$. As to the inflation and the unemployment target we assume $\alpha_5 > 0$ and $\alpha_6 < 0$. Incidentally, we notice that the latter means an inverse relationship between inflation and unemployment, as postulated by the Phillips curve. The lagged discount variable is introduced because we allow a partial adjustment of the actual to the optimal discount rate, with $1 - \alpha_7$ the coefficient of adjustment. It is to be noticed that $\alpha_7 = 0$ means complete adjustment within each period.

To begin with, equation (6) has been estimated with quarterly data covering the period 1958:I -1975:IV. The discount rate r has been observed on the official interest rate on advances. For the short-term domestic interest rate we have taken the interest rate on call money. For the foreign short-term interest rate the average yield on three Euro-dollar deposits has been used for the period from 1962, while the yield on American Treasury paper was used before 1962. A dummy-variable has been included to account for this discontinuity.

The estimation results for equation (6) over the whole sample period are shown in table 1.

TABLE 1. Estimation results* for:

$$r_t = \alpha_1 + \alpha_2 r_t^d + \alpha_3 r_t^F + \alpha_4 B + \alpha_5 \dot{p}_t + \alpha_6 u_t + \alpha_7 r_{t-1} + \alpha_8 d_t$$

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	DW	R^2
1958: I-1975: IV**:	0.9326	0.1276	0.0824	0.3070	0.0258	−0.1864	0.7172	1.45	0.97
	(6.82)	(4.37)	(3.13)	(3.60)	(1.68)	(5.18)	(17.48)		
1958: I-1963: IV**:	1.4551	0.2261	0.1095	−0.8434	0.0033	−0.1702	0.5916	1.91	0.89
	(2.24)	(1.77)	(1.13)	(1.24)	(0.14)	(2.49)	(4.42)		
1964: I-1969: IV:	1.1479	−0.0091	0.1522	−0.0929	0.0252	−0.1214	0.6379	2.28	0.97
	(3.20)	(0.18)	(3.72)	(0.30)	(0.98)	(2.61)	(7.27)		
1970: I-1975: IV:	0.8647	0.1181	0.0919	0.3587	0.0413	−0.2533	0.7171	1.33	0.94
	(1.22)	(1.74)	(1.07)	(1.20)	(0.53)	(1.63)	(6.32)		

* The figures in parentheses are t-statistics.

** The coefficient of the interest rate dummy is −0.1227 (1.10) and −0.3788 (1.78) respectively with $d_t = 0$ before 1962.

In several respects the empirical results for the period 1958:I-1975:IV are not very satisfactory. Firstly, the coefficient of the balance of payments variable has a positive sign which is contrary to our *a priori* expectations. The price coefficient α_5 is insignificant but has the expected positive sign. It is interesting to note that these results remain unaffected by alternative measures for the external position.

In our description of discount rate policy we emphasized the gradual shift in the considerations leading to a change of the discount rate, movements in domestic and foreign interest rates being an important consideration in recent years. This indicates a shift in the reaction function which can be verified empirically. Therefore we have re-estimated equation (6) for three subperiods. The estimation results are also reported in table 1. The results show that the coefficient of the balance of payments variable has the *a priori* expected sign in the first two sub-periods, although it is insignificant. We note also that over the period 1964:I-1969:IV the coefficient of the domestic interest rate α_2 has the wrong sign and is insignificant. This may be the result of multicollinearity among interest rates [cf. Fase (1973, 1976)]. However, it is noteworthy that in this very period the foreign interest rate had a significant influence. Again we see that the coefficient of the price variable does have the expected sign but is insignificant in all cases, while the coefficient of the unemployment variable, α_6, is always significant.

It is remarkable that over the subperiods the ajustment coefficient $1-\alpha_7$ has decreased gradually from 0.40 to 0.30. This indicates a decline in the speed of adjustment of the actual to the optimal discount rate. In other words, the recognition lag of the monetary authorities has increased slightly over the years.

The implicit trade-offs, indicating which changes in the targets compensate for each other according to the monetary authorities, can be calculated from the estimated coefficients of the reaction function. The trade-off between unemployment and inflation is 7.22 for the whole reference period. Hence, in the view of the monetary authorities 1% more unemployment is offset by over 7% additional inflation. Computation of trade-offs for the balance of payments variable is only sensible in those subperiods where the value of α_4 has the correct sign. In the first subperiod the trade-off between the balance of payments and unemployment was −4.96, in other words it would not have affected discount rate policy if, *ceteris paribus*, the balance of payments had improved with Fl. 200 million and at the same time unemployment had decreased with 1%. Apparently, the balance of payments was of some importance to discount rate policy in this period. However, the trade-off has come down to only −0.77 in the second subperiod. We did not calculate the trade-off between the balance of payments and inflation as the coefficients of both variables either are not significant or have the wrong sign.

In summary we may conclude that the movements of interest rates in the domestic and foreign money market and the development of the trade cycle, measured by the rate of unemployment, were the main determinants of the discount rate policy in the Netherlands over the period 1958-1975. The influence of inflation and the external position of the economy on the other hand, was not found to be very significant. Finally, deviding the sample-period into three subperiods shows that the reaction function was not very stable. The recognition lag increased somewhat over the observation period.

4.2 Credit control policy

Monetary policy in the Netherlands is primarily a quantity oriented policy. Credit control is therefore an important instrument. As with discount rate policy, stabilization is the main objective, so that credit control is aimed at the same overall target variables. Contrary to the discount rate policy the dependent variable in the credit restriction reaction function is a qualitative variable, taking the value 1 in periods with restrictive policy, and 0 elsewhere.

Several estimation techniques have been developed for situations with limited dependent variables, such as our dichotomous credit restriction variable [see appendix B for technical details]. In this section we confine ourselves to the results obtained with the probit and logit model and relegate the OLS and GLS estimation results to appendix B (section 4).

In the probit model we estimate the equation:

$$P_t = F(\nu_t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\nu_t} e^{-\frac{1}{2}\tau^2} \, d\tau \tag{7}$$

where P_t is the probability of a credit restriction in period t, given the state of the economy as represented by the «dosage» U_t, with

$$\nu_t = \beta_1 + \beta_2 B_t + \beta_3 \dot{p}_t + \beta_4 u_t \tag{8}$$

where the β are the parameters to be estimated. The variables have the same meaning as before. We know from experience that, with a regime of fixed exchange rates, a deficit on the balance of payments leads to a policy of tight money. On that basis we expect $\beta_2 < 0$ As a higher level of unemployment gives rise to a policy of easy money it is also plausible to assume that $\beta_4 < 0$. The coefficient of inflation β_3 may, however, be expected to have a positive sign.

The logit model may be summarized as follows:

$$P_t = \frac{1}{1 + e^{-\nu_t}} \tag{9}$$

where P_t is the probability of a credit restriction in period t given the state of the economy, again represented by ν_t where ν_t is again given by equation (8).

Equations (7) and (9) have been estimated for the period 1958:I-1975:IV. The estimation results are given in table 2.

TABLE 2. Estimation results of the probit and logit model 1958 : I – 1975 : IV

MODEL	alternative	β_1	β_2	β_3	β_4	«R^2»
probit	u	0.47	–4.76	0.49	–1.28	0.69
	u_{-2}	1.86	–5.78	0.51	–2.20	0.81
logit	u	0.77	–8.08	0.88	–2.25	0.69
	u_{-2}	3.28	–9.95	0.97	–3.99	0.82

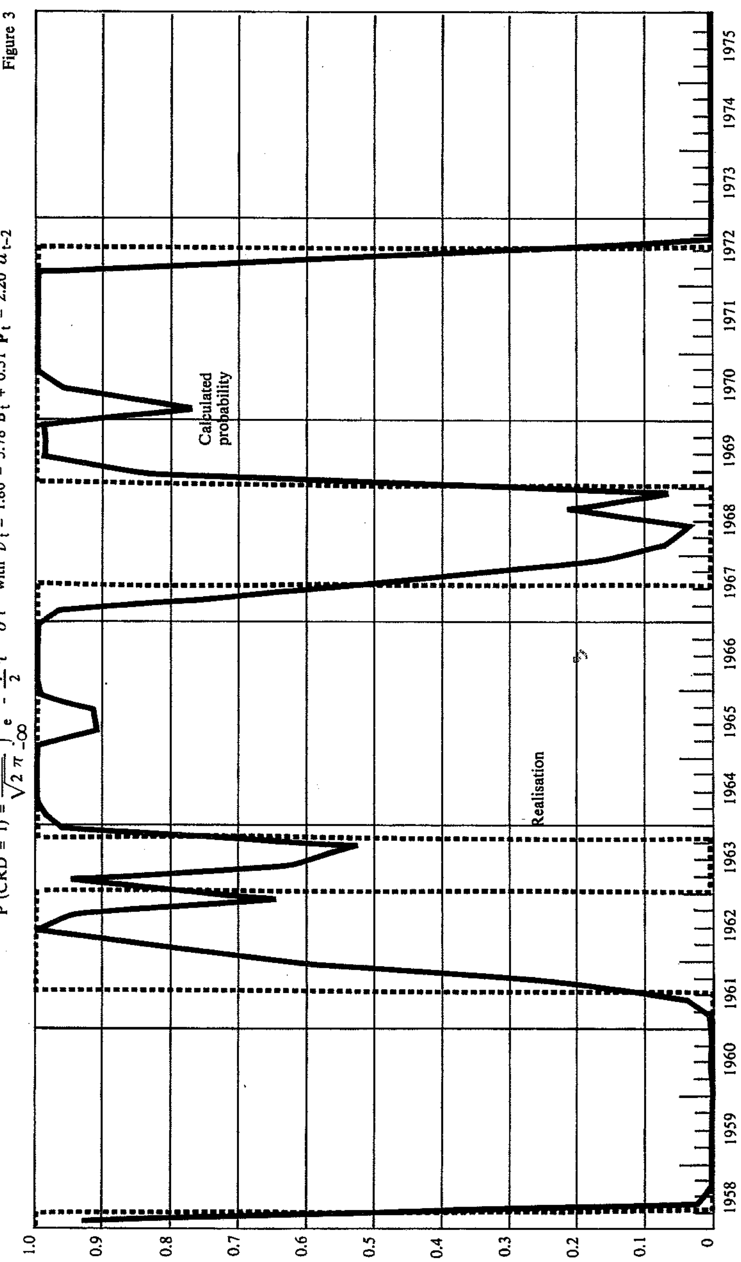
The table shows two alternatives for each model, in which all coefficients have the expected sign. We do not report standard errors, as we are not able to compute them, but the OLS and GLS estimates may indicate that these coefficients are significant (see appendix B.4). The overall fit seems to be satisfactory, and slightly better if we lag the unemployment variable two quarters. In table 2 this is indicated as alternative u_{-2}. With this alternative the three target variables explain 80% more than when it is assumed that the observations of the dependent variable are random and independent drawings from a binomial distribution. Figure 3 gives for the probit model a graphic impression of the performance with alternative u_{-2}. Il illustrates that in only 5 of the 72 cases the difference between the calculated probability using equation (7) and the realisation exceeds 0.5. This happens in 1961:III, when direct credit restrictions were applied for the first time, during the temporary suspension in 1963:I-1963:III and in 1972:II, which is the last quarter with a direct credit control. The results of the logit model are almost completely in accordance with these findings.

It must be noted that for economic reasons we expect an immediate reaction of the authorities on a change in the unemployment rate. Therefore, alternative u, in which unemployment has been included without a lag, seems preferable to alternative u_{-2}.

CREDIT RESTRICTION EQUATION

$$P\,(CRD = 1) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\nu_t} e^{-\frac{1}{2}\tau^2} \, d\tau \quad \text{with } \nu_t = 1.86 - 5.78\, B_t + 0.51\, \dot{P}_t - 2.20\, u_{t-2}$$

Figure 3



Moreover, the theoretical framework only allows for current values of the final targets in the reaction function. We present both alternatives because the latter is more satisfactory from a statistical point of view, as it has a better fit.

The trade-off between the balance of payments and unemployment is –2.62 in the probit model with alternative u_{-2} . Hence, the probability of a credit restriction remains unchanged when the balance of payments increases with Fl. 100 million and unemployment decreases with somewhat over 1/4%. Less weight has been attached to inflation as is clear from the fact that the trade-off between balance of payments and inflation is 11.35. It means that the monetary authorities are willing to give up over 1% of inflation for an increase of the balance of payments of Fl. 100 million. The trade-off between unemployment and inflation equals 4.33 indicating that according to the authorities 1% more inflation outweighs 0.23% additional increase of the unemployment rate. For the logit model the corresponding trade-offs are resp. –2.50, 10.29 and 4.12.

Finally we studied the stability of the estimated relationship by splitting the sample period into two equal subperiods: 1958:I-1966:IV and 1967:I -1975:IV. In doing so it became apparent that the estimated reaction function of credit control is presumably not very stable. In the first subperiod notably the balance of payments position was important to explain credit policy, while in the second the rate of unemployment almost exclusively determined the existence ou non-existence of credit control. If for example in 1967.III unemployment had not been 2.5% but slightly higher, let us say 2.6%, the fit of the logit and probit model would even have been perfect. This illustrates the fact that a stability analysis with a dichotomous dependent variable is not really feasible with the relatively few observations we have. The estimated coefficients depend to a large degree on a few crucial observations. In the above-mentioned case the perfect fit can be achieved by including one other arbitrary explanatory variable. The number of degrees of freedom is then, as it were, brought down from 1 to 0.

From our empirical exploration of credit control we may conclude that the balance of payments and the rate of unemployment are the main determinants of credit control policy during the sample period, much more so than inflation. Together these three target variables explain to a large degree the credit policy pursued.

4.3 Discount rate and credit control policy

As said before Dutch monetary policy is basically a quantity oriented policy, supported by discount rate policy if necessary. The question arises to what extent credit policy accounts for discount rate policy. There are several ways to deal with this question. One method tried by us is to include the credit restriction dummy, CRD, as an explanatory variable in equation (6). The estimation results are shown in table 3. These results show that the coefficient of the dummy CRD is never significant. This means that the assumed relationship between discount rate policy and credit restriction policy is not apparent. Therefore, we do not need to modify our earlier conclusion with regard to the discount rate reaction function.

Another way to do justice to the relationship between discount rate policy and credit control is by jointly estimating the variation in these two instruments. In order to be able to do this it is necessary to classify changes in the discount rate in such a way that a dosage response model, similar to the one used for credit control policy can be formulated. For the joint estimation of this seemingly unrelated set «dosage-response» type reaction functions Zellner and Lee's (1965) joint estimation procedure, yielding asymptotically efficient estimators can be used. Although this seems an attractive approach, we shall not pursue it further here. For the time being we confine ourselves to the single-equation estimation results given in tables 1 and 2, which deliberately neglect the joint variation of the two policy instruments.

TABLE 3. Estimation results* for:

$$r_t = \alpha_1+\alpha_2 r^d_t + \alpha_3 r^F_t + \alpha_4 B + \alpha_5 \dot{p}_t + \alpha_6 u_t + \alpha_7 r_{t-1} + \alpha_8 d_t + \alpha_9 CRD_t$$

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_9	DW	R^2
1958: I-1975: IV**	0.9385 (6.43)	0.1280 (4.33)	0.0820 (3.08)	0.3008 (3.02)	0.0264 (1.62)	–0.1887 (4.63)	0.7183 (17.26)	–0.0122 (0.12)	1.45	0.97
1958: I-1963: IV**	1.3158 (1.86)	0.1976 (1.42)	0.0829 (0.76)	–0.3386 (0.30)	0.0082 (0.31)	–0.1690 (2.41)	0.6215 (4.24)	0.0835 (0.57)	1.90	0.89
1964: I-1969: IV	1.2028 (3.20)	–0.0222 (0.40)	0.1649 (3.55)	–0.1166 (0.37)	0.0215 (0.80)	–0.0909 (1.33)	0.6049 (5.82)	0.0639 (0.62)	2.46	0.97
1970: I-1975: IV	1.3157 (1.60)	0.1262 (1.85)	0.0919 (1.07)	0.0460 (0.11)	0.0403 (0.52)	–0.3033 (1.88)	0.7185 (6.37)	–0.5787 (1.08)	1.43	0.95

* The figures in parentheses are t-statistics.
** The coefficient of the dummy-variable α_8 is –0.1221 (1.09) and –0.2831 (1.03) respectively, with $d_t = 0$ before 1962.

5. Previous studies

Despite the fact that the analysis of macro-economic reaction functions started only a decade or so ago, some authors have achieved interesting results and it is useful to look at our own findings in the perspective of this literature. A particular characteristic, which the studies known to us have in common, is that they mainly focus on the behaviour of monetary authorities but ignore fiscal policy. Beginning with the empirical studies by Dewald and Johnson (1963) and Reuber (1964), a sheer number of studies have been published by the profession. Table 4 attempts to summarize this empirical literature, which has been classified by us according to four different topics. Having done this, we hasten to add that our classification does not claim to be the only possible one, particularly because sometimes we had to make a rather arbitrary choice.

A striking characteristic of the reported studies is the large variety of dependant variables representing the instruments of monetary policy. These variables can roughly be divided into two groups.

The first group comprises quantity variables, usually indicating open market policy, or, in a wider sense, money supply. Notably in the case of the money supply these policy variables often include components which cannot be controlled completely by the monetary authorities. In that case these quantities are proxies for this policy, which may fail to uncover the intentions of the policy maker if the policy were not effective in the sense that it did not affect these proxies. We believe this to be undesirable for a proper measurement of policy responses. To avoid this we employed in the present analysis the dichotomous credit restriction variable to describe policy behaviour with a minimum loss of information.

The second group of dependent variables comprises the interest rate variables, which is very often the discount rate. In some cases a short-term interest rate, which is assumed to reflect the interest rate policy, is used. However, against a short-term interest rate as proxy the same objection can be raised as we did against the money supply as a proxy of quantity policy.

TABLE 4: Survey of empirical reaction function studies

Author	Policy instrument	Sample period	Policy targets				Mean lag in quarters
			B	u	$\dot{p}$	g	
U.S.A.							
Dewald and Johnson (1963)	a) Currency plus demand deposits (money supply)	1952 I – 1961 IV	□	+ +	□	+ +	3.1
	b) Treasury bill rate	1952 I – 1961 IV	—	— —	+	— —	0.2
Goldfeld (1966)	Potential demand deposits	1950 III – 1962 II	□	+ +	□	— —/+ +	1.6
Wood (1967)	Federal Reserve's demand for securities (open market policy)	1952 I – 1963 IV	+ +	+	— —	— —	
Havrilesky (1967)	Total reserves	1952 I – 1965 IV	□	+ +	— —	+ +	
Christian (1968)	a) Currency plus demand deposits	1952 I – 1966 IV	+	+ +	— —	+ +	7.3
	b) Treasury bill rate	1952 I – 1966 IV	□	—	+	—	2.5
Teigen (1969)	a) Rate of change of unborrowed reserves plus currency (open market policy)	1953 I – 1964 IV	+ +	□	□	—	negative
	b) Discount rate	1953 I – 1964 IV	(+ +) *			+	1.7
Friedlaender (1973)	Net free reserves	1954 IV – 1960 IV	□	□	+ + *	+ +	
	(open market policy)	1961 I – 1964 IV	— *	□	— —	□	
Froyen (1974)	Monetary base	1953:2 – 1961:1	— *	+ +	+ *	+ +	
		1961:2 – 1969:1	— *	+ +	— —	+ +	
		1969:2 – 1972:12	+ +	+ +	□	+ +	
Havrilesky, Sapp and Schweitzer (1975)	Federal funds rate	1964:1 – 1966:11	— —	□	+ +		
		1966:12 – 1967:11	□	— —	+ +		
		1968:7 – 1968:12 (1)					
		1969:1 – 1970:1	+ *	+ *	+ +		
		1967:12 – 1968:6 (1)					
		1970:2 – 1971:7	— —	— —	— — *		
		1971:8 – 1972:9	+ + *	□	+ +		
		1972:10 – 1974:2	— —	— —	+ +		
Froyen (1975)	Discount rate	1955:1 – 1968:6	— —	□	+ +		
		1968:7 – 1972:12	— —	— —	+		
Lombra and Torto (1975a)	Federal Reserve's demand for securities (open market policy)	1952 I – 1963 IV		+ +	— —	—	
Canada							
Reuber (1964)	Money supply	1949 I – 1961 IV		+ +	+ + *	+ +	(0.8)
Helliwell et al. (1971)	Short-term interest rate	1958 I – 1968 IV	— —		+ +		0.6
Australia							
Jonson (1974)	a) Bond rate	1959 III – 1971 IV	— —	— —	+		1.7
	b) Bank cash ratio	1959 III – 1971 IV	□	— —	+		0.3
England							
Fisher (1970)	a) Bank rate	1955 I – 1968 IV	— —	— —	+	□	0.8
	b) Special deposits	1955 I – 1968 IV	+ *	— —	+	□	10.6
	c) Hire purchase rate	1955 I – 1968 IV	—	— —	+	□	2.3
Pissarides (1972)	a) Bank rate	1955 IV – 1968 IV	— —	— —	+ +		1.3
	b) Hire purchase rate	1955 IV – 1968 IV	—	— —	+ +		1.9
Belgium							
Villanueva (1972)	Discount rate	1957 II – 1968 IV	—	— —	+	□	4.9
Befahy (1972)	Discount rate	1961 I – 1971 I	— —	□	+ +	□	4.9
Dendievel and Eeckhoudt (1974)	a) Currency plus demand deposits	1953 II – 1969 IV	— *	— *	□	□	17.8
	b) Discount rate	1953 II – 1969 IV	—	— —	+ +	+	7.8
Germany							
Befahy (1972)	Discount rate	1961 I – 1971 I	— —	□	+ +	□	1.9
Mutoh (1976)	Domestic credit of central bank	1960 I – 1973 IV	□		— —	— —	
Herring and Marston (1977)	Controlled change in effective unborrowed reserves	1960 III – 1971 I	— — *	+ +(2)	— —	+ +	
France							
Befahy (1972)	Discount rate	1961 I – 1971 I	□	□	+	□	3.4
Netherlands							
Van den Akker (1960)	Discount rate	1951 I – 1958 IV	— —	□			
Befahy (1972)	Discount rate	1959 I – 1971 I	□	— —	+ +	□	
This study	a) Credit restriction	1958 I – 1975 IV	— —	— —	+	□	
	b) Discount rate	1958 I – 1975 IV	□	— —	+	□	2.5

(1) One equation is estimated with the observations for both subperiods taken together.
(2) In fact the percentage change in new manufacturing orders is used instead of unemployment and a negative sign is reported.
EXPLANATORY NOTE: the symbols have the following meaning:
+ + large (significant) positive effect
+ small (not significant) positive effect
□ no effect found
— — large (significant) negative effect
— small (not significant) negative effect
* wrong sign
blank means not investigated and in the last column that no Koyck lag has been estimated

The first target variable in the summary concerns the balance of payments (B). Here too we found that various ways of measurement have been used. The most unusual, if not outright odd, indicators are found in Teigen (1969), Havrilesky et al. (1975), and Helliwell et al. (1971). In his open market reaction function Teigen uses the Treasury bill rate, reflecting the monetary authorities' concern over potential capital inflow (2). Helliwell et al., who study the Canadian case, employ also this U.S. interest rate as an indicator for the balance of payments while Havrilesky et al. take the dollar exchange rate of the German Mark as an indicator for the U.S. external position (3). In the remaining studies B represents either the trade balance, the total balance of payments or the gold and foreign exchange reserves.

As can be seen the impact of the balance of payments position on monetary policy varies widely among the reported studies. It is true that a sheer amount of the studies reports the expected sign for the balance of payments variable: positive for open market or money supply policy, and negative for discount rate policy. However, this outcome is somewhat biased by the fact that a few studies, in particular Dewald and Johnson (1963) and this paper, qualify results with the wrong sign as incorrect and infer that the balance of payments position was not a major determinant. Thus, the survey of the literature seems to give support to our conclusion that discount rate policy hardly responded to the balance of payments. Surprisingly enough in this matter, no differences seem to exist between open and closed economies.

The table shows further that monetary policy did respond to shifts in the rate of unemployment (u), and in the rate of inflation ($\dot{p}$). For these two variables a wrong sign was found only occasionally, and in most of the studies the influence of these variables is assessed as important. With regard to unemployment these results are in accordance with our own findings. This is much less true of inflation as target of monetary policy. It is true that both in our credit control equation and in our discount rate equation we found the expected positive sign for this variable, but its response was rather weak.

With regard to the growth target (g), a major difficulty is its measurement. To illustrate this Goldfeld (1966) employs two different indicators producing completely contrary results. This and similar difficulties with other studies explain why in our survey the label «wrong sign» has never been used in the growth target column. Apart from this it appears that in the American and Canadian studies growth as a target of economic policy plays a more important role than in the European studies. As argued before we believe that for the Netherlands there is no reason to consider growth as a target of monetary policy.

Several authors pay a great deal of attention to the lags with which monetary authorities respond, especially because this uncovers the recognition lag of the monetary authorities. In this respect the length of the time interval between the observations is important. Froyen (1974, 1975) argues that monthly data are preferable to quarterly data because this may remove the possibility of reverse causation and facilitate the determination of the direction of causality. Despite this, with the exception of Froyen and Havrilesky et al. (1975) who also relies on monthly data, all the reported studies use quarterly data (4). In order to judge the estimated speed of adjustment, we computed the mean lag, particularly in those studies which include a Koyck distributed lag in the estimated reaction function. The

(2) Teigen also uses the Treasury bill rate as an explanatory variable in the discount rate equation and finds, as expected, a strong positive correlation. If we consider the Treasury bill rate also as a proxy for the balance of payments in this equation, then the positive sign is theoretically wrong.

(3) For purpose of presentation we have in our table changed the sign reported by Helliwell et al. and Havrilesky et al.

(4) We do not believe that, by using quarterly data, reverse causation may yield a large bias in estimating our reaction functions. In the Netherlands the sum of the recognition lag of the authorities and the transmission lag of monetary policy is most probably larger than one quarter.

result is given in the last column of the table (5). In the case of other lag specifications such as Froyen's (1974, 1975) Almon-lags, the mean lag is associated with the particular target variable and we found it too complicated to summarize those results in the format of our table. Again the results did not converge. However, the mean lag of 2.5 quarters which we found in our discount rate equation seems plausible in comparison to other results.

An important feature of some of the reported studies is the assessment of the stability of the estimated reaction function. Christian (1968), and in his spirit, Villanueva (1972), investigated the stability by means of the «moving regressions» technique. Others, including ourselves (re-)estimate the equations for particular subperiods. Friedlaender (1973), Froyen (1974), and Havrilesky et al. (1975) make a break-down into subperiods by presidential administrations, or by periods with different monetary regimes. It appears from nearly all studies that the reaction functions of the monetary authorities are not very stable. An exception is Keeley (1976) whose paper could not be included in the summary because no estimation results are reported. He concludes that on the whole the American authorities reacted consistently with regard to unemployment, price stability and balance of payments.

Keran and Babb (1969), and Lombra and Torto (1973) also estimated reaction functions for the American open market policy. However, they did not include ultimate policy targets, but only intermediary targets as explanatory variables. Keran and Babb conclude that the Federal Reserve aimed at stabilizing income, employment and prices, but that in fact, their behaviour was dominated by a desire to prevent short-run instability in the financial system, which is potentially destabilizing. Lombra and Torto's estimates serve mainly to illustrate a methodological discussion on the endogeneity of monetary policy to which we will come back in the next section.

In summary we may conclude that our survey of the literature suggests that, while by and large a concensus emerges on the response of the monetary policy to the balance of payments, the rate of unemployment and the rate of inflation, the size of these responses shows substantive variation between studies. This is hardly surprising when the results relate to different countries but it is remarkable for those studies that refer to the same country. A possible explanation is the fact that the reaction function includes both the preferences of the policy maker and the structure of the economy. With regard to the preferences, lasting stability and consequently stable responses, are not to be expected.

6. Concluding remarks

The two reaction functions estimated in this paper by no means exhaust the policy instruments available to the Netherlands Bank during the past two decades (6). Assuming that monetary policy is sufficiently represented by our two equations, the analysis has yielded insight into some aspects of revealed policy behaviour. However, our conclusions should be considered with great care, as the reaction functions are quite unstable and as the calculated trade-offs show large error margins.

On the whole, discount rate policy responded closely to cyclical movement of the unemployment rate rather than to the external position or the existence of credit restrictions. This independence of the external position contrasts the view that within a regime of fixed exchange rates monetary policy is meant to achieve external balance, and fiscal policy internal balance. Interestingly enough we found a close relationship between discount rate policy and variations in domestic and foreign short-term interest rates.

(5) In Reuber's (1964) reaction function the dependent variable occurs both with a one and a two quarter lag. The values of the coefficients are such that the adjustment becomes cyclical. Although the measured mean lag is low in this case (0.8 quarter), the adjustment process takes quite a long time, which leads Reuber to conclude that the policy maker reacts rather slowly.

(6) For details we refer to Den Dunnen (1973).

Dichotomous credit restriction behaviour was satisfactorily explained by the cyclical variation of the unemployment rate and by the external position, while the rate of inflation reflected only a rather weak influence.

What do these results mean? They indicate that the central bank adjusts its instruments in order to respond to undesirable deviations from particular target variables, with discount rate behaviour being constrained by market interest rates. This finding contrasts the traditional treatment of policy instruments as exogenous variables. The endogeneity has been the focus of attention in recent years [see the important paper of Goldfeld and Blinder (1972), Crotty (1973, 1976), Goldfeld (1976), Lombra and Torto (1973, 1974, 1975b), Warburton (1975)]. The main argument concerns the consideration that an endogenous monetary policy generates economic data which will lead to seriously biased results in estimating macro-econometric models.

These and related problems have been extensively studied by Goldfeld and Blinder (1972) who infer both from Monte Carlo experiments and theoretical reasoning in particular cases, that the estimation bias of the policy multiplier is substantial in the tiny reduced-form policy models, like the St. Louis-equation. However, the statistical and conceptual problems are not all that serious in structural models. In the first place they argue that the unjustified inclusion of a few endogenous policy variables among a long list of predetermined variables will hardly affect the TSLS-estimates. Secondly they believe that the misspecification affects only some equations of the model since policy variables appear only in very few structural equations.

Finally we like to add that we always have the option of extending the structural model with some reaction functions, reflecting the behaviour of the monetary authorities. To allow for such a richer specification of macro-econometric models, detailed analysis of individual reaction functions may provide information on the question whether the authorities have responded systematically to shifts in the targets indeed. In a way this analysis is similar to the early analysis of single consumption or investment functions.

APPENDIX A – On the data

1. Description of the variables

r Interest rate on advances.
Source: Annual Reports, De Nederlandsche Bank N.V.

CRD Credit restriction dummy; in 1958:I, 1961:III – 1962:IV, 1963:IV – 1967:II and 1969:I – 1972:II CRD = 1; in the other quarters CRD = 0.

r^d Interest on call money secured by Treasury paper.
Source: Quarterly Statistics, De Nederlandsche Bank N.V.

r^F Up to 1961:IV: Treasury bill rate USA.
Source: International Financial Statistics, IMF.
From 1962:I: Gross yield three-month Euro-dollar deposits.
Source: Quarterly Statistics, De Nederlandsche Bank N.V.

d Dummy r^F: $d = 0$ up to 1961:IV
$d = 1$ from 1962:I

B Balance of payments, current account on transactions basis, moving average of last four quarters, adjusted for 1% net national income at market prices.
Source: Quarterly Statistics, De Nederlandsche Bank N.V.

$\dot{p}$ Four quarter rate of growth of consumer price index.
Source: Monthly Bulletin of Social Statistics, Centraal Bureau voor de Statistiek.

u Registered male labour reserve in % of total male labour force excl. self-employed (seasonally adjusted).
Source: Statistisch Bulletin, Centraal Bureau voor de Statistiek.

2. The data are listed in table A.1.

TABLE A.1 – Data used

Period		Interest rates (%)			B (billions of guilders)	%	
		r (1)	r^d	r^F		$\dot{p}$	u
1957	I	4.25	3.24	3.17	–0.329	7.53	1.5
	II	4.25	3.03	3.16	–0.403	8.70	1.7
	III	5.04	3.41	3.38	–0.361	13.56	2.1
	IV	5.50	3.48	3.34	–0.229	12.57	2.6
1958	I	5.09	3.18	1.84	–0.047	7.83	3.5
	II	4.40	2.55	1.02	0.110	5.07	4.1
	III	4.00	2.25	1.71	0.243	–1.55	3.9
	IV	3.58	1.93	2.79	0.302	–1.71	3.5
1959	I	3.31	1.42	2.80	0.313	–1.39	3.2
	II	3.25	1.46	3.02	0.317	–1.40	2.9
	III	3.25	1.40	3.55	0.324	3.62	2.7
	IV	3.88	1.98	4.30	0.359	4.26	2.4
1960	I	4.00	1.77	3.94	0.306	3.61	2.0
	II	4.00	1.97	3.09	0.282	4.57	1.8
	III	4.00	1.60	2.39	0.285	1.22	1.6
	IV	4.00	1.37	2.36	0.214	0.61	1.4
1961	I	4.00	0.83	2.38	0.178	0.76	1.3
	II	4.00	0.75	2.33	0.126	0.45	1.2
	III	4.00	0.85	2.32	0.101	1.65	1.2
	IV	4.00	1.63	2.48	0.055	2.56	1.1
1962	I	4.00	1.74	3.36	–0.055	2.70	1.0
	II	4.36	2.41	3.45	–0.060	6.76	1.1
	III	4.50	1.33	3.68	–0.071	2.95	1.1
	IV	4.50	1.78	3.91	–0.014	2.20	1.1
1963	I	4.04	1.80	4.02	–0.052	4.97	1.2
	II	4.00	1.46	3.70	–0.032	2.11	1.0
	III	4.00	1.48	3.96	–0.047	2.30	1.0
	IV	4.00	1.28	4.14	–0.030	3.87	0.9
1964	I	4.47	2.05	4.07	–0.176	3.62	0.9
	II	4.64	2.51	4.28	–0.322	5.79	0.9
	III	5.00	2.62	4.28	–0.360	7.71	1.0
	IV	5.00	2.70	4.62	–0.301	6.08	1.0
1965	I	5.00	3.06	4.66	–0.179	4.30	1.1
	II	5.00	3.25	4.94	–0.064	2.60	1.1
	III	5.00	2.96	4.69	–0.019	3.65	1.1
	IV	5.00	3.50	5.16	–0.138	4.82	1.1
1966	I	5.00	4.01	5.43	–0.366	6.57	1.2
	II	5.33	4.70	5.78	–0.362	6.47	1.1
	III	5.50	4.55	6.64	–0.401	5.40	1.4
	IV	5.50	4.53	6.92	–0.348	4.60	1.9
1967	I	5.40	4.64	5.64	–0.262	3.02	2.5
	II	5.00	4.33	5.04	–0.228	2.86	2.9
	III	5.00	3.97	5.17	–0.242	3.81	3.0
	IV	5.00	3.96	6.08	–0.250	4.16	2.9
1968	I	5.00	3.29	5.88	–0.207	3.99	2.6
	II	5.00	4.24	6.62	–0.151	3.71	2.7
	III	5.00	3.99	6.12	–0.239	3.33	2.5
	IV	5.07	4.67	6.77	–0.141	3.88	2.1
1969	I	5.50	5.07	7.98	–0.135	7.56	1.9
	II	5.95	5.86	9.59	–0.167	8.16	1.9
	III	6.63	7.51	10.91	–0.164	7.22	1.9
	IV	7.00	5.49	10.60	–0.198	6.92	1.8
1970	I	7.00	6.95	9.45	–0.297	2.83	1.6
	II	7.00	6.52	8.90	–0.414	2.79	1.5
	III	7.00	6.43	8.36	–0.482	4.25	1.5
	IV	7.00	5.98	7.54	–0.718	4.72	1.5
1971	I	7.00	4.38	5.54	–0.789	6.53	1.5
	II	6.52	1.96	6.70	–0.773	7.54	1.6
	III	6.22	4.01	7.69	–0.641	7.65	1.9
	IV	5.50	4.68	6.46	–0.452	8.14	2.5
1972	I	4.86	3.01	5.26	–0.321	7.85	3.1
	II	4.50	1.75	5.07	0.064	7.85	3.2
	III	4.26	0.67	5.55	0.358	7.29	3.2
	IV	4.11	3.04	6.00	0.698	8.07	3.3
1973	I	4.50	1.65	7.70	0.930	7.73	3.2
	II	5.02	2.95	8.52	1.162	8.15	3.1
	III	6.90	6.90	11.02	0.850	8.26	3.0
	IV	8.19	8.19	10.19	1.215	7.97	3.1
1974	I	9.00	9.33	9.07	1.180	8.66	3.4
	II	9.00	9.02	11.46	1.046	8.81	3.5
	III	9.00	6.90	13.22	1.389	9.86	3.8
	IV	8.29	7.08	10.51	0.947	10.88	4.2
1975	I	7.72	6.42	7.61	0.661	10.62	4.7
	II	7.00	2.35	6.52	0.673	10.31	5.2
	III	6.57	1.38	7.33	0.439	10.56	5.6
	IV	5.50	4.40	6.84	0.571	9.53	5.6

(1) Calculated as a weighted average.

APPENDIX B

On the estimation of a dichotomous regressand

1. A credit restriction either occurs or it does not. The credit restriction reaction function attempts to account for this, with a regressand y_t that can take only two values such that

$$y_t = \begin{cases} 0 & \text{if the credit restriction does not occur} \\ 1 & \text{if the credit restriction occurs} \end{cases}$$

To analyse this situation several statistical methods have been developped in the literature. The purpose of this appendix is to present briefly the essentials of three of those methods, viz.: the linear probability model, the logit model and the probit model. In this discussion we heavily rely on the extensive literature, but we refer only to the text books of Finney (1971), Goldberger (1964) and Goldfeld and Quandt (1972).

2. The linear probability model assumes that the dichotomous dependent variable is a linear function of the regressors x:

$$y_t = x_t' \beta + u_t \tag{B.1}$$

with x_t a vector nonstochastic independent variables, β the coefficient vector, u_t a random disturbance, where $Eu_t = 0$. The conditional expectation of y for a given set of x, may be viewed as the conditional probability that a credit restriction will occur. Thus the calculated y, $\hat{y}$, is an estimate of this probability, i.e.

$$Pr\{ y_t = 1 \mid x_t \} = x_t' \hat{\beta}$$

Goldberger has pointed out that the disturbances u in this model are heteroscedastic, depending on the value of the x and the coefficients β. Therefore, generalized least squares estimation of (B.1) is more appropriate than OLS. However, since the true covariance matrix is unknown a two step procedure should be applied.

A major difficulty with the linear probability model is that it allows the calculated y_t to fall outside the unit interval, which means a negative estimated variance of u_t. Another drawback is that the method becomes rather tedious when $\hat{y}_t$ approaches 0 or 1. In such a case the estimated variance becomes very small leading to a dominant weight of the corresponding observation in the GLS estimation procedure.

3. To avoid these difficulties other approaches are available, of which we consider the probit and the logit models. Both methods perform a monotonic transformation of the dichotomous dependent variable (or probability) y_t to the $(-\infty, \infty)$ interval.

The probit model uses the inverse of the cumulative normal distribution function $F^{-1}()$, to perform this transformation of y_t, such that

$$F^{-1}\left(\Pr\{y_t = 1 \mid x_t\}\right) = x_t'\beta$$

with

$$\Pr\{y_t = 1 \mid x_t\} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x'\beta} e^{-\frac{1}{2}\tau^2}\, d\tau = F(x_t'\beta) \qquad \text{(B.2)}$$

Probit analysis originated in biology and may be justified by the assumption that individuals respond to specific stimuli, $x_t'\beta$, as soon as the dosage $\partial_t = x_t'\beta$ reaches a critical threshold z_t. Returning to our dichotomous variable y_t we have:

$$y_t = \begin{cases} 0 & \text{for } \nu_t < z_t \\ 1 & \text{for } \nu_t > z_t \end{cases}$$

and assume the z_t to follow a normal distribution.

The logit model uses the transformation

$$\log \frac{P_t}{1-P_t} = x_t'\beta$$

leading to the estimating equation

$$P_t = \frac{1}{1+e^{-x_t'\beta}} \qquad \text{(B.3)}$$

with

$P_t = \Pr\{y_t = 1 \mid x_t\}$ as discussed before.

To estimate equations (B.2) or (B.3) several procedures are available. We have considered the maximum likelihood method. In both cases the logarithmic likelihood function is

$$L = \sum_{t=1}^{T} \{y_t \log P_t + (1-y_t)\log(1-P_t)\} \qquad \text{(B.4)}$$

where P_t is given in (B.2) or (B.3) and T is the number of observations.

Substituting equation (B.2) or (B.3) into (B.4) shows that L is a function of the β and the observations on y_t and the x_t. The estimates have been obtained numerically by the routine ZXMIN from the IMSL-library, using a quasi Newton algorithm. In our case this routine did not cause any difficulty in reaching the optimum. The estimates were easily determined to an accuracy of 4 or 5 digits.

The variance-covariance matrix of the ML estimators is usually derived by means of the inverse of the information matrix. In the present case the information matrix can be derived from (B.4), using $Ey_t = p_t$, and reads in matrix notation as

$$-E\,\frac{\partial^2 L}{\partial\beta\,\partial\beta'} = \sum_{t=1}^{T} \frac{1}{P_t(1-P_t)}\,\frac{\partial P_t}{\partial\beta}\left(\frac{\partial P_t}{\partial\beta}\right)'$$

However, if for a number of observations the value P_t (in the maximum) approaches 0 or 1, the elements of the information matrix become very large and therefore it is impossible to determine the variances and the covariances. This is what happened to the credit restriction equation, and therefore we were unable to present standard deviations for the estimation results in table 3. For the same reasons we could not use the scoring method, but had to resort to the IMSL-routine mentioned above. This routine, however, also gave inaccuracies and rounding off problems, when calculating the Hessian-matrix numerically. According to the IMSL reference manual this may occur when the optimum is located in a very few steps.

In order to compare the goodness of fit for different specifications for the same dependent variable, we define

$$«R^2» = 1 - \frac{\sum_{t=1}^{T}(y_t - P_t)^2}{\sum_{t=1}^{T}(y_t - \bar{P})^2} \cdot \frac{T}{(T-k)}$$

with

$$\bar{P} = \sum_{t=1}^{T} y_t / T$$

with k the number of explanatory variables, including the constant term. This quantity is used as the R^2 in regression analysis. The analogy is apparent: the numerator of the second term gives the unexplained part of the variance after the regression while the denominator comprises the total variance of the dependend variable in deviation from its mean. The multiplication by T/ (T-k) serves to adjust for the number of degrees of freedom.

4. The estimation results for OLS and GLS are reported in table B.1.

TABLE B.1 OLS and GLS estimates* for the credit restriction function: CRD = $\beta_1 + \beta_2 B + \beta_3 \dot{p} + \beta_4 u$

Method of estimation	Alternative	β_1	β_2	β_3	β_4	R^2
OLS	u	0.62 (0.10)	–0.56 (0.10)	0.06 (0.01)	–0.17 (0.04)	0.60
	u_{-2}	0.83 (0.11)	–0.43 (0.10)	0.05 (0.01)	–0.25 (0.04)	0.66
GLS	u	0.72 (0.05)	–0.45 (0.03)	0.04 (0.00)	–0.16 (0.02)	0.57
	u_{-2}	0.87 (0.05)	–0.40 (0.03)	0.03 (0.00)	–0.19 (0.02)	0.62

* Standard errors in parentheses.

The table shows that the estimated coefficients are significant and have the expected sign. This result may justify our believe that the coefficients obtained with our probit and logit model, where we could not calculate standard errors, are significant too. Again we find a slightly better fit with the alternative u_{-2} than with the theoretical preferable alternative u. The trade-offs between B and u_{-2}, B and $\dot{p}$, and u_{-2} and $\dot{p}$ are –1.75, 8.97 and 5.11 respectively for the OLS-estimates and –2.04, 15.41 and 7.54 for the GLS-estimates. Generally they do not differ very much from the trade-offs obtained in the probit and logit model, which are given in the main text of this paper.

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